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Multitude of progress and unmediated problems of solar PV in Bangladesh

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ABSTRACT

The aims of this paper are to demonstrate a critical review of the multitude of progress in solar PV research and applications in Bangladesh since its inception in 1996 till 2010. Our studies show that Bangladesh has been experiencing an accelerated shift towards solar PV to meet the gap between demand and supply of electricity along with conventional electricity generation. Despite the present generation of electricity from solar PV is 15–20 MW, both public and private sectors have started several solar PV projects to generate several hundred of MW by the upcoming years. This paper has also tried to identify the critical barriers for widespread dissemination of solar PV in Bangladesh and has discussed possible ways to overcome those barriers as well.

Contents

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1. Introduction

1.1. Energy scenario of Bangladesh at a glance

Congruent on demand and supply of electricity is a measure of a country's development index. But Bangladesh has been facing a severe power crisis for decades. Reserves (e.g., natural gas and coal) of commercial primary energy sources in Bangladesh are not adequate enough to meet the development needs of the country [1]. Power generation in the country is almost entirely dependent on fossil fuels, mainly natural gas that accounted for 81.4% of the total installed electricity generation capacity (5248 MW) in 2006 [2]. By that year, only about 42% of total population had been connected to electricity [3]. At the end of FY 2009–2010, only 47% of total population is now being connected to grid electricity having per capita generation of 220 kWh, leaving vast majority being deprived of a power supply. At present there is high-unsatisfied demand for energy which is growing by more than 8% annually. The government of Bangladesh has declared that it aims to provide electricity for all by the year 2020 [4].

Due to the high cost of transmission and distribution and mismatch load-demand criteria, a large number of rural settlements have not been connected to the grid. Therefore, it is very clear that many villages and isolated areas may not be connected in the near future to conventional electricity generation and distribution networks.

In FY 2009–2010, total generation capacity was 5376 MW (upto May'10) including 3331 MW in public sector and 2045 MW in private sector (including REB) [5]. In the public sector, a good number of generation units have become very old and have been operating at a much-reduced capacity. As a result, their reliability and productivity are also poor. For the last few years, actual demand could not be supplied due to shortage of available generation capacity. Besides, due to shortage of gas supply some power plants are unable to reach their usual generation capability (Table 1).

Maximum generation of 4606 MW (as of April 14, 2010) was supplied till to-date. So maximum generation of 2087 MW in 1995–1996, 3218 MW in 2001–2002, 3458 MW in 2002–2003, 3622 MW in 2003–2004, 3751 MW in 2004–2005, 3812 MW in 2005–2006, 3718 MW in 2006–2007, 4130 MW in 2007–2008 and 4162 MW in 2008–2009 could not end power crisis in the country (Fig. 1) [5].

1.2. Solar energy potentials of Bangladesh

Bangladesh is situated between 20.308° and 26.388° north latitude and 88.048° and 92.448° east longitude with an area of 147,500 km^2, which is an ideal location for solar energy utilization. Estimation of the potential of solar energy in Bangladesh is done using a GIS based GeoSpatial Toolkit (GsT) and NASA Surface Meteorology and Solar Energy (SSE) solar radiation data. Due to the limited solar radiation data in Bangladesh, a NASA SSE data set for the period from July 1983 to June 1993 was used and compared to the measured data from the Renewable Energy Research Center (RERC), Dhaka University, for six different stations in Bangladesh. The data vary from 0.66% to a maximum 4.52% from the NASA SSE data set at the same locations. The GeoSpatial Toolkit provides the solar map of Bangladesh and it shows that the solar radiation is in the range of 4–5 kWh/m^2/day on about 94% surface areas of Bangladesh (Fig. 2) [6,7]. The average sunny hours per day are 6.5, and the annual mean solar radiation is 0.2 kW/m^2. This indicates that Bangladesh theoretically receives approximately 69,751 TWh of solar energy every year, i.e., more than 3000 times higher than the current (2006) electricity generation in the country. The average annual power density of solar radiation is typically in the range of 100–300 W/m^2. Thus, with a solar PV efficiency of 10%, an area of 3–10 km^2 is required to establish an average electricity output of 100 MW, which is about 10% of a large coal or nuclear power plant [8]. A study suggested that 6.8% (10,000 km^2) of Bangladesh's total land is necessary for power generation from solar PV to meet electricity demand of 3000 kWh/capita/year [9]. Another study found that total household roof area is about 4670 km^2 [10] which is about 3.2% of total land area of the country. In urban area (Dhaka city) 7.86% of total land is suitable for solar PV electricity generation [11]. Considering the grid availability, only 1.7% of the land in Bangladesh is assumed technically suitable for generating electricity from solar PV [12]. The capacity of grid-connected solar PV is derived using the annual mean value of solar radiation (200 W/m^2) and a 10% efficiency of the solar PV system. Thus, the technical potential of grid-connected solar PV in Bangladesh is calculated as about 50,174 MW [6].

Table 1
Bangladesh power sector at a glance [31].

Sl. No.	Items	FY 2009–2010 (up to May'10)
1.	Generation capacity, MW	5376
2.	Maximum generation, MW (April 14, 2010)	4606
3.	Net generation, MkWh (FY 2008–2009)	26,533
4.	Transmission line, km	8391
5.	Grid substation capacity, MVA	
	(a) 400 kV and 8230 kV	6850
	(b) 132 kV	9626
6.	Distribution line, km	266,460
7.	Number of consumers (million)	12.00
8.	Number of village electrified	53,281
9.	Per capita generation, kWh	220
10.	Access to electricity	47%

2. Commercial perspective of solar PV in Bangladesh

Out of about 25 million households of the country, only around 5.5 million had been brought under the network of conventional electricity till to-date [5]. Since the rural network is characterized by a comparatively lower consumer density, it often becomes difficult and uneconomic to extend lines to certain remote locations within the command area of a Palli Bidyut Samity (a government organization to manage electricity transmission and distribution to rural settlements). Moreover, some remote areas are not likely to be covered by the grid network due to inaccessibility and low consumer density. Renewable energy technologies are considered as viable technical options for such remote areas, especially for ensuring equitable development of all areas and different cross-sections of socio-economic-groups.

There is no doubt that renewable energy technologies will play a significant role in the future development scenario of the country, especially when the capital costs of such technologies will further become competitive with grid electricity. This is expected to happen globally within the next decade, as there is the historical trend of capital cost reduction for solar PV technology all over the world. But until such time, the developing countries like Bangladesh should take efforts to establish the technical reliability and social acceptability of such technologies through demonstration and pilot projects. It is remarkable here that in other developing countries such projects are currently supported through subsidies from the respective governments.

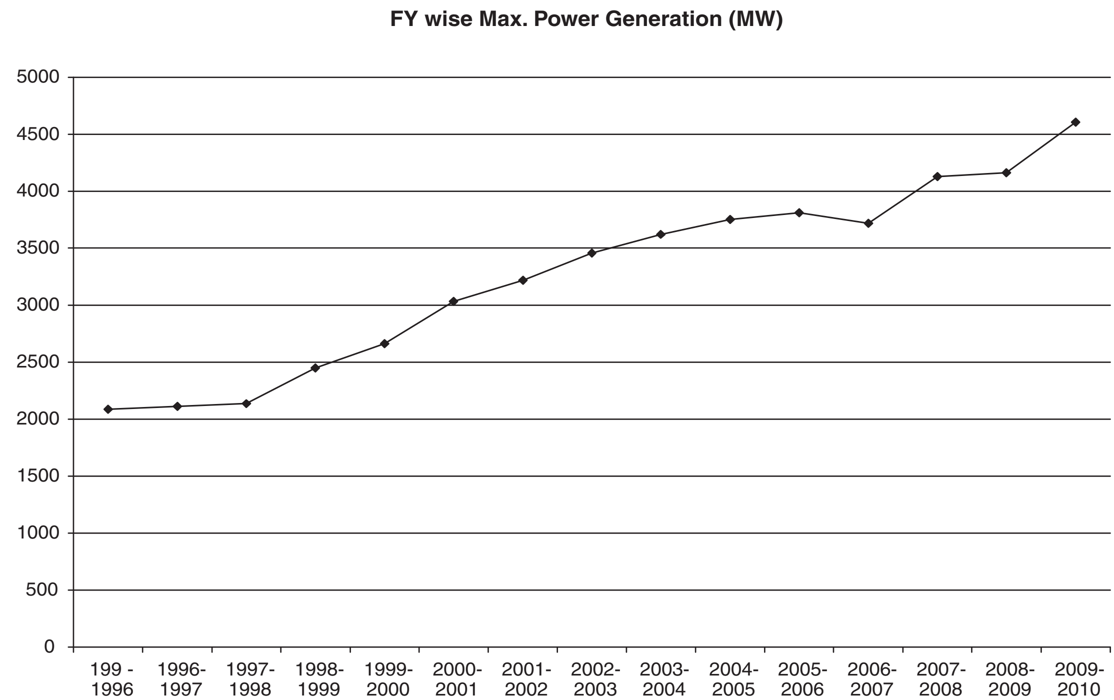

Fig. 1. FY wise maximum generation.

3. Potential uses of solar PV in Bangladesh

3.1. Solar home system (SHS)

The system consists of a 20–100 watt peak (Wp) PV array, a rechargeable battery and a charge controller. Both the array size and sunlight availability determine the amount of electricity available for daily use [13]. With an appropriate sunlight regime, the system has proven to be competitive for remote households. The SHS is thus implemented in many developing countries. In Bangladesh, by the end of 2010, a total of about 645,033 SHSs had been installed [14].

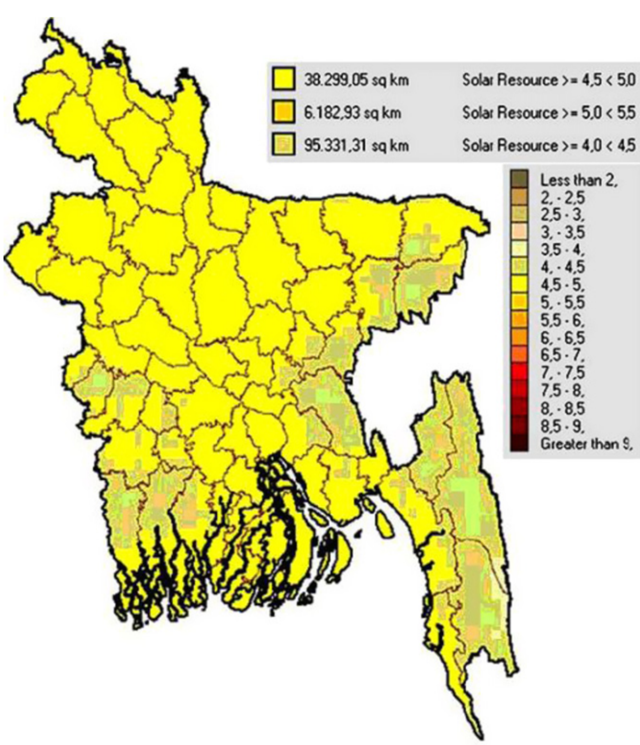

Fig. 2. Solar insolation potential of different regions of Bangladesh.

3.2. Hybrid system

A recent study by Mondal and Denich [6,7] indicates that the selected locations blessed with a considerable annual average global solar radiation (3.81–6.47 kWh/m^2/day), are prospective candidates for the deployment of PV–diesel–battery hybrid power system. Their simulation results for all selected locations indicate that the most economically feasible system for 50 rural off-grid households would be composed of 6 kW PV array together with a 10 kW diesel generator and 10 numbers of batteries of which each has a nominal voltage of 2 and capacity of 800 Ah, and the penetration of solar PV is 43%. Due to high diesel cost only diesel based power generation is not economically feasible. This study also indicates that the remote settlements located in Bangladesh are prospective candidates for the deployment of the proposed PV–diesel–battery hybrid system for electricity generation due to the favorable daily average solar radiation which varies between 3.8 and 6.5 kWh/m^2 and the diesel price is almost the same all over the country. Utilizing this system for electricity generation in comparison with the diesel generator-only situation would decrease the operating hours of diesel generators and consequently would reduce the diesel consumption and would lead to reduction in emissions of GHG.

3.3. Grid connected PV

Different types of grid interactive systems are being tested in countries where extensive utility grid lines are available. A PV array is connected and synchronized to the grid using an appropriate power conditioning sub-system that converts the DC energy to alternating current (AC) energy synchronized to the grid energy [15]. Therefore, no additional energy storage is necessary. The grid itself is the storage medium for such a grid-interactive system,

which delivers energy to the grid as long as enough sunshine is available. The system is usually integrated directly into structural elements of buildings (roof, facade). Therefore, the system has the following advantages [16]:

- It reduces both energy and capacity losses in the utility distribution network, as the electric generators are located at or near the site of the electrical load.
- It avoids or delays upgrades to the transmission and distribution (T&D) network where the average daily output of the PV system corresponds with the utility's peak demand period (afternoon peak demand during summer as a result of loads from cooling).
- It is cost competitive, since the savings for building material is considered, i.e., no roof tiles are needed when solar panels are installed.

4. Recent status of solar PV application in Bangladesh

4.1. Cumulative generation and future plan

The information obtained from the database of Ministry of Power, Energy and Mineral Resources (MPEMR) Bangladesh related to the net generation of electricity from solar PV till to date is accumulated below [5]:

1. Present solar power generation: 15–20 MW.
2. Power development board (PDB), rural electrification board (REB) and infrastructure development company limited (IDCOL) are distributing SHS to the people living in the off-grid areas. IDCOL has already distributed 450,000 SHS across the country through different NGO.
3. PDB has already installed nearly 11 kW solar power in the Chittagong hill tracts (CHT) area, nearly 230 W solar power in Angorpot and Dahagram Chitmahal Area and 115 W in the WAPDA office building.
4. A solar panel with capacity of 21.2 kW has been installed at the Prime Minister's Office.
5. Nearly 10 MW solar plant will be installed by PDB in Sarishabari (2–4 MW), Regional Training Office, Rajshahi (1 MW), Rajabarihat, Godagari (2–4 MW), Kaptai Power Plant (4–5 MW) following independent power producer (IPP) model. Preparation of tender documents is underway.
6. Preliminary development project proposal (PDPP) has been prepared to cover 4 isolated islands under solar and wind power.
7. REB has taken project for solar irrigation system. 20 irrigation pumps will be energized by solar power under this project.

4.2. Recent energy initiatives by the government

To increase access to electricity among the people living in off grid, isolated and in accessible remote areas by solar home systems (SHSs) and to achieve the objective government has set targets for developing renewable energy resources to 5% of total power demand by 2015 and 10% by 2020, government has taken a number of initiatives for efficient energy use and reduced consumption of energy [5].

- Steps taken to revise building code taking into account issues related to energy efficiency and solar energy potentials.
- To build awareness among the children, steps taken to incorporate energy efficiency and solar energy issue in the academic curricula of School/Madrasa/Colleges.
- Installation of solar panel in the government, semi government and autonomous organizations within next 3 years.
- Use of CFL bulb in all ministries and power sector entities.
- Conventional street lights will be replaced by LED and solar subsequently.
- Public awareness for energy conservation.
- Discontinuation of incandescent bulb and electric heater gradually.
- Limited use of air conditioners keeping temperature within 25 °C.
- Encourage the business community to use solar energy.
- Introduction of energy star rating system in the electric appliances through Bangladesh Standards and Testing Institution (BSTI).
- Discouraging use of neon sign in the markets/shopping malls at night.
- Closing of markets and shopping malls within 8 p.m.
- Steps taken to introduce pre-paid metering system all over the country to reduce system loss and to lower the use of electricity.

4.3. Financial incentives through REP

A renewable energy policy (REP) was revised and finalized by the Ministry of Power, Energy, and Mineral Resources (MPEMR) in December 2008 [17]. In the REP 2008, the government of Bangladesh decided to establish an independent unit, the Sustainable Energy Development Authority (SEDA) instead of Renewable Energy Development Authority (REDA) for expediting the use of renewable energy for power generation [18]. SEDA in conjunction with the power division of the MPEMR shall be responsible for determining the priorities for renewable energy technology (RET) development and program implementation; SEDA shall support capacity building, technology development and market development sufficient to boost the share of electricity generated from RETs. In the REP 2008, the government has proposed the following fiscal incentives on investment:

1. Existing renewable energy financing facilities shall be extended so that they are capable of accessing public, private, donor, carbon emission trading, and providing financing for renewable energy investments.
2. To promote renewable energy in the power sector, all renewable energy equipments and related raw materials in producing renewable energy equipments will be exempted from charging 15% value added tax (VAT).
3. In addition to commercial lending, a micro-credit support system will be established.
4. SEDA will consider providing subsidies to utilities for installation of solar, wind, biomass, or any other renewable or clean energy projects.
5. Renewable energy project investors shall be exempted from corporate income tax for a period of 5 years.
6. An incentive tariff may be considered for electricity generated from renewable energy sources, which may be 10% higher than the highest purchase price of electricity by the utility from private generators.
7. For successful implementation of renewable energy projects and initiatives lending procedure will be simplified and strengthened.

5. Status of government initiated solar PV projects

5.1. Solar PV pilot project under REB

This solar PV pilot project was based on a French financial grant implemented in the Narsingdi district of the country by Rural Electrification Board (REB), a semi-government organization. A total of 795 PV units of 5 systems ranging from 6 to 92 Wp have been supplied or installed. These solar PV units are divided into 2 categories:

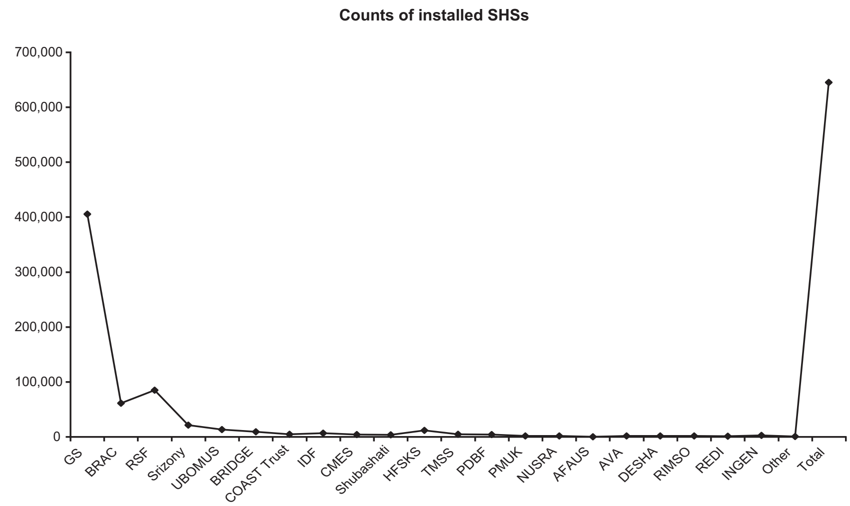

Fig. 3. No. of installed SHSs by 23 partner organizations (PO) of IDCOL upto August 2010.

(1) standalone systems and (2) charging station based battery system. Under this project, solar PV systems were also installed at one rural health clinic for running fans, light and a refrigerator. The main objective of this project was to test the various commercial solar PV systems under the rural socio-economic conditions of Bangladesh and to incorporate feedback in design of replication activities in remote rural areas. Technically, this project was successful except for the deep cycle battery storage system. The financial mechanism for users was not successful.

5.2. *Chittagong hill tracts solar electrification project of BPDB*

The Bangladesh Power Development Board (BPDB) has conducted a feasibility study for solar PV in the Chittagong hill tracts region and is currently implementing solar PV projects in three sub-districts in this region. It concerns different types of solar PV applications, including SHSs, water pumps, vaccine refrigerators, street lamps and centralized power station. Upto January 2005, BPDB installed solar PV systems of total capacity of 54 kW in the Juraicharisub-district: 10.8 kW for centralized systems, 7.2 kW for street lighting, and 36 kW for 300 SHSs (ranging 75–129 W). In two other sub-districts Beliachari and Borkol, 1800 SHSs are provided. BPDB expected to install a total capacity of around 150 kW in Chittagong hill tracts regions. The overall charge of supervision and bill collection of different systems was planned to be done by the beneficiary management committee composed of local people [19].

6. Solar PV dissemination by private sectors and NGOs

6.1. *Solar PV projects by IDCOL*

IDCOL promotes dissemination of solar home system (SHS) in the remote rural areas of Bangladesh through its Solar Energy Program with the financial support from the World Bank, Global Environment Facility (GEF), KfW, GTZ, Asian Development Bank and Islamic Development Bank. IDCOL started the program in January 2003 and its initial target was to finance 50,000 SHSs by the end of June 2008. The target was achieved in September 2005, 3 years ahead of schedule and US$ 2.0 million below estimated project cost. IDCOL then revised its target and decided to finance 200,000 SHSs by the end of 2009. This was also achieved by May 2009. Now IDCOL's target is to finance 1 million SHSs by the end of year 2012. Up to August 2010, a total of 645,033 SHSs have already been installed under the program [14] (Figs. 3 and 4).

IDCOL's Solar Energy Program is one of the fastest growing renewable energy programs in the world. It has brought in positive changes in the livelihood of remote rural areas of Bangladesh by providing access to electricity. Chairman of the Senate Foreign Relation Committee of the United States, John Kerry in his speech at the World Bank Head office on 19 November 2009 mentioned IDCOL solar home system (SHS) project as a good example of literally life-altering project of the World Bank. IDCOL implements the program through 23 partner organizations (POs).

6.1.1. *Solar irrigation pump projects by IDCOL*

IDCOL is financing an 11.2 kWp solar photovoltaic (PV) power plant to run a submersible solar water pump at Shapahar, Naogaon with a capacity of 250,000 l per day at 35 m head. A total of 64 solar PV modules with 175 Wp capacity each will be installed to provide the required power to run the pump. Total project cost has been estimated to be BDT 5.275 million, it will be financed through term loan facility following project financing mechanism and a grant from GEF fund. Once completed, it is expected to provide irrigation facilities to more than 3 ha of land owned by a number of farmers in three seasons. The whole land area under the project will be utilized for paddy cultivation (3 crops) using buried pipe method [14].

Another similar project to be financed by IDCOL is an 8.4 kW solar photovoltaic (PV) power plant by Rural Service Foundation (RSF) to run a 1 cusec (cubic feet per second) submersible solar water pump at Baniali, Barinagar, Jessore. A total of 48 solar PV modules with 175 Wp capacity each will be installed to provide the required power to run the pump. It is expected to provide irrigation facilities to more than 22.5 ha of land through this project and 22 farmers will benefit from it. Buried pipe method will be used to irrigate 5.352 ha of land for rice crop for three months and 17.13 ha of land for vegetable cultivation for nine months [14].

Given the energy crisis and rising price of petroleum products, it is important to explore alternative energy sources for irrigation to ensure both food and energy security. If these projects become successful, solar photovoltaic based water pumping solution for irrigation might be implemented in larger scale in Bangladesh. It is expected to save 8000 l of diesel worth of BDT 0.36 million in a year through these projects only.

6.1.2. *Solar micro grid projects by IDCOL*

IDCOL board recently approved financing a 100 kW solar photovoltaic (PV) based micro-grid by PUROBI Green Energy Limited

Division	SHS
Barishal	99137
Chittago	132003
Dhaka	152615
Khulna	88988
Rajshahi	90784
Sylhet	81506
Total	**645033**

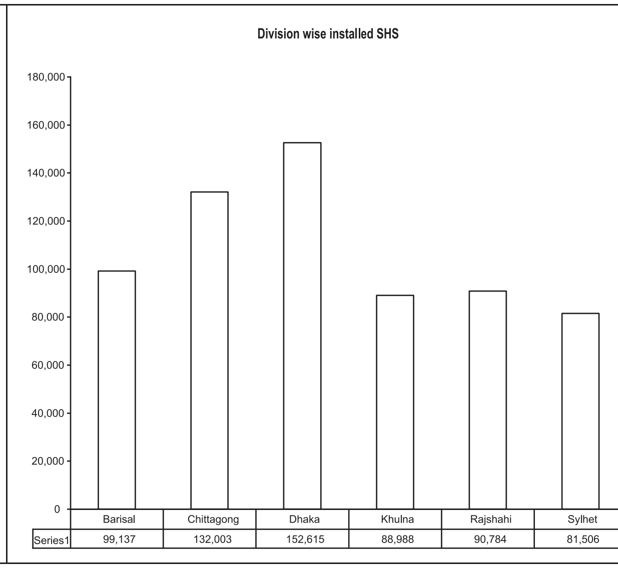

Fig. 4. Division wise installed SHSs by IDCOL.

(PGEL) at Sandip island, Chittagong. A 40 kW diesel generator will be integrated into the proposed power plant in order to ensure adequate power supply during periods of low solar radiation. Total project cost is BDT 55.37 million and it will be financed through mix of debt, equity and grant from KfW [14]. PGEL is a consortium of four NGOs namely Bangladesh Rural Integrated Development Grub-Street Economy (BRIDGE), Integrated Development Foundation (IDF), Upokolio Bidyut and Mohila Unnoyon Samity (UBOMOUS) and Rural Energy and Development Initiative (REDI). Once completed, this project is expected to supply electricity to adjacent 390 shops, 5 health centers and 5 schools [14].

6.2. Solar PV programs of Grameen Shakti

Grameen Shakti was established in 1996 to develop and popularize renewable energy resources. It has been appreciated globally for its outstanding approach of micro-credit for developing SHSs in rural areas. Grameen Shakti has played a pioneering role in the successful initiation and implementation of renewable energy programs, especially its solar PV program is internationally renowned. By the end of the year 2010, GS had installed 405,295 SHSs throughout the country [20].

6.3. Solar PV program of BRAC

The Bangladesh Rural Advancement Committee (BRAC) is the largest NGO in Bangladesh. In 1997, it launched its solar energy program. The BRAC renewable energy program was started to electrify remote locations in the country. By the end of 2010, the program installed more than 61,008 SHSs. BRAC also installed two grid-interactive PV systems. The program involved installing PV systems in BRAC branch offices (such as training centers, schools, and health clinics), micro-enterprise projects (such as carpentries and tailoring shops), and in government-owned buildings (such as rest houses and cyclone shelters). A few SHSs have been setup for wealthier house holds [21].

7. Research and development

Different institutes, universities and research organizations (both public and private) are carrying out research and development (R&D) activities in various fields of renewable energy technologies. R&D activities of Bangladesh are characterized by many constraints, including lack of expert knowledge and financial resources. Different organizations and their field of interest related to R&D of RETs are presented in Table 2.

8. Unmediated barriers for solar PV diffusion

There are plenty of barriers hindering the widespread deployment of solar PV. Different types of barriers experienced from the past are described below.

Policy barriers
- Lack of legal, regulatory and policy framework for market oriented solar PV programs. Most of the solar PV programs in Bangladesh are primarily technology driven and focused on R&D, rather than emphasizing promotion and encouragement of commercialization and private sector involvement.

Institutional barriers
- Renewable energy based provision of modern energy services is dealt with by various ministries, agencies and institutions. Making good coordination between them is a necessity to efficiently make use of limited human and financial resources in this area.
- Lengthy and difficult process for permission.
- Dependency on the national budget for implementation of activities, which creates uncertainties in allocation of project financing as well as time delays associated with decision making.
- Limited spatial distribution of suppliers limits access to solar PV technologies.

Technical barriers
- Lack of standards and quality control for solar PV equipment.
- Lack of domestic manufacturing.
- Difficulties of firm dispatch in utility grid operations.
- Bulk procurement of solar PV technologies is limited due to the current small market for solar PV based modern energy services. Hence the (technical) infrastructure to support solar PV development does not exist.
- Local manufacturing and/or assembly of solar PV components are currently very limited, although the knowledge, skills, expertise and facilities are available in the country.
- Limited technical capacity to design, install, operate, manage and maintain solar PV based modern energy services, mainly as a result of lack of past activities in this new field.

Table 2
Institutes involved in R&D of solar PV in Bangladesh.

Technology	Involved organizations	Remarks
Solar photovoltaic balance of systems	Garmeen Shakti CMES IFRD	Local manufacturing of all balance of system components (like charge controller, cable, inverter, converter) possible
Solar water heaters	RERC, Dhaka University IFRD CMES	Manufacturing with local design and fabrication facility possible
Solar cooker – parabolic	IFRD ANANDO	IFRD has successfully field-tested its design which can quickly boil water on clear sunny days. Such solar cookers are now on sale at a cost of Tk.450.00 (US$ 9.00) at IFRD. ANANDO is also manufacturing and marketing it's products with imported materials and design
Solar cooker – box type	IFRD CMES	IFRD's design is made of locally available raw materials. The manufacturing costs of such a cooker are about Tk. 800 (US$ 16.00) excluding the cost of utensils. The cookers are now being sold at IFRD
Solar dryer	IFRD BRRI BAU	Different types have been designed and tested with locally available materials
Solar wood seasoning plant	BFRI	A simple, inexpensive and effective solar kiln has been developed for seasoning timber using solar radiation. The kiln can be constructed conveniently with locally available materials. Timbers of different species and dimensions can be seasoned throughout the year in the solar kiln
Solar passive architecture	BCSIR	A solar house has been designed and built in the BCSIR campus, the purpose is to keep the house warm in winter and cool in summer

Market barriers

- Limited knowledge on the solar PV market potential.
- The high upfront cost at the end user level for solar PV is a major barrier to the increased use of solar PV sources for the provision of modern energy services.
- Market distortions by subsidies or grant-based hardware installation programs.
- No dedicated financing for solar PV activities exists with financial institutions now. The capacity within the financial institutions and power utilities to appraise solar PV proposals and requests for loan is limited or non-existing.
- Government budgets for subsidizing RE projects are limited as the demand for financing the various national priority areas (health, education, disaster management, etc.) is great.
- The currently small and dispersed size of the solar PV market in Bangladesh does not facilitate benefits such as economies of scale.
- Availability of solar PV resources is very site specific, requiring detailed analysis of the local specific conditions.

Economic, financial and financing barriers

- Below loan-run marginal cost pricing and price distortion.
- High initial capital costs.
- Financial institution biases and unfamiliarity with financing solar PV projects.
- Lack of access to credit and appropriate financing mechanisms for solar PV.

Information barriers

- Lack of information about solar PV resources, technical/economic information, equipment suppliers, and potential financiers.
- Lack of awareness of solar PV in public, industry, utility, financial institutions and policy-makers.
- Availability and access to existing solar PV resource information is not centralized, rather it is scattered among various sectors; e.g., public sector, development assistance, R&D Centres and academia.
- Little empirical knowledge on the costs and benefits of the range of technologies available for providing solar PV based modern energy services exists.

Human resource barriers

- Limited expertise in business management and marketing skills.
- Limited in country capacity for solar PV data collection and analysis.
- Lack of expertise and services in system design, installation, operation and maintenance of renewable energy technologies.
- Limited in-country capacity for renewable energy project development.

9. Discussion: promotion of solar PV

The availability of a new technology or innovation does not guarantee adoption of the same. It is therefore necessary to understand the factors that influence potential adopters during the various stages of the decision making process.

The PV commercialization process is inextricably linked to the basic components of adoption theory. The classical adoption process includes the following steps in the decision to purchase or reject a new product (technology): awareness, interest, evaluation, trial and adoption/rejection [22]. The existing models of technology adoption propose that potential adopters develop an interest in a product by obtaining and assimilating knowledge about it [23]. This knowledge helps people form views and develop attitudes, which persuade them to either adopt or reject the product [24]. Roger in his innovation decision model elaborately explained the knowledge as a series of "prior conditions" such as previous practice, felt needs/problems, innovativeness and norms of the social system that serve as antecedents to the knowledge state. Rogers also identifies socioeconomic characteristics, personality variables and measures of communication behavior as basic characteristics of the decision-making unit. All these contribute to knowledge acquisition [25,26].

Characteristics or attributes of an innovation that affect its adoption include: relative advantage, compatibility, complexity, trialability and observability [24]. Relative advantage is the degree to which an innovation is perceived by the adopter to be superior to preceding ideas. Compatibility is the extent to which an innovation is perceived as being consistent with the potential adopter's experiences, values and needs. Complexity is the degree to which an innovation is seen as being difficult to understand and use. Trialability is the degree to which an innovation may be experimented with or used on a limited basis. Observability is the degree to which the results of an innovation are seen by others.

The government can play a leading role, through the formulation of favorable policies, by showing a practical commitment and by enhancing public awareness of the potential of PV in all walks of life. Often, the majority of the people constituting the potential market are unaware of the existence and systems' capabilities of PV technologies [27]. The lack of information about renewable energy benefits, economic and financial costs is a major barrier to adoption [28]. It is therefore crucial that appropriate and well-targeted information be provided to certain key groups of potential

users. The dissemination of information is a key factor in the diffusion of PV systems. The government could institute a financing system which favors PV diffusion, provide temporary tax exemptions for the purchase of PV equipment and facilitate reduction in energy price distortion. The government could also provide financing and access to affordable credit line plans in order to convert potential users into actual users. Additionally, allowing duty free imports of solar equipment, components and appliances would help in lowering the initial costs of PV systems. It can also play a role in forging collaborations, technology transfers and providing institutional support for local and international research institutions. The government could also facilitate an appropriate economic and political climate to attract international investment in the production of PV systems. The government could ensure a healthy market by restricting monopolies, fostering development of standards and codes of practice. The government should also encourage the promotion of public and industry awareness of the environmental and other benefits of PV. This can be accomplished through advertising campaigns, PV documentation programs that reach the people through radio, TV, newspapers, highway billboards and setting up demonstration sites. Government intervention is therefore necessary in a number of ways to promote solar energy. Governments should consider subsidies for PV technologies in order to stimulate the PV market [29].

The absence of institutional frameworks and legal structures that create the proper climate for investments in solar PV is a significant barrier in Bangladesh. There is a need to develop system standards for all the main system components. Standards also are required to be established for certification or qualification for designers and installers. The initial costs of PV systems are high and hence the acceptance of PV systems will depend on the financial viability of investments in PV systems [30]. Therefore, well-adapted financial schemes and financial support are essential for the dissemination of these technologies. Lack of long-term capital is a key barrier [28].

The traditional accounting procedures do not account for pollution costs and scarcity value of diesel. If these are included in the cost calculation of widely used conventional diesel-based decentralized systems, then solar photovoltaic (SPV) technologies may be an ideal alternative to conventional oil-based systems in the decentralized power-generating sector [29].

10. Conclusion

Improving access to energy in Bangladesh is a fundamental contribution to poverty reduction. As energy is prerequisite for social and economic development it is essential to move towards sustainability in energy systems both in order to protect natural life-support systems on which humanity depends, and to eradicate poverty. Energy demand in Bangladesh is rising swiftly. Demand is outstripping the production and transmission and distribution capability. Especially power demand exceeds generation capacity. There are also some bottlenecks in power transmission and distribution system. All these leads to increased load shed and poor quality of power supply.

Bangladesh is endowed with vast resources of solar radiation. The long-term average sunshine data indicates that the period of bright (i.e., more than 200 W/m^2 intensity) sunshine hours in the coastal region of Bangladesh vary from 3 to 11 h daily. The global radiation varies from 3.8 kWh/m^2/day to 6.4 kWh/m^2/day. These data indicate that there are good prospects for solar thermal and photovoltaic application in Bangladesh. Harnessing these resources appears to be a promising solution for improving the quality of life of rural villagers, who are unlikely to have access to conventional electricity supply in the foreseeable future.

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